SENSORS & ACTUATORS (SESSION-2)

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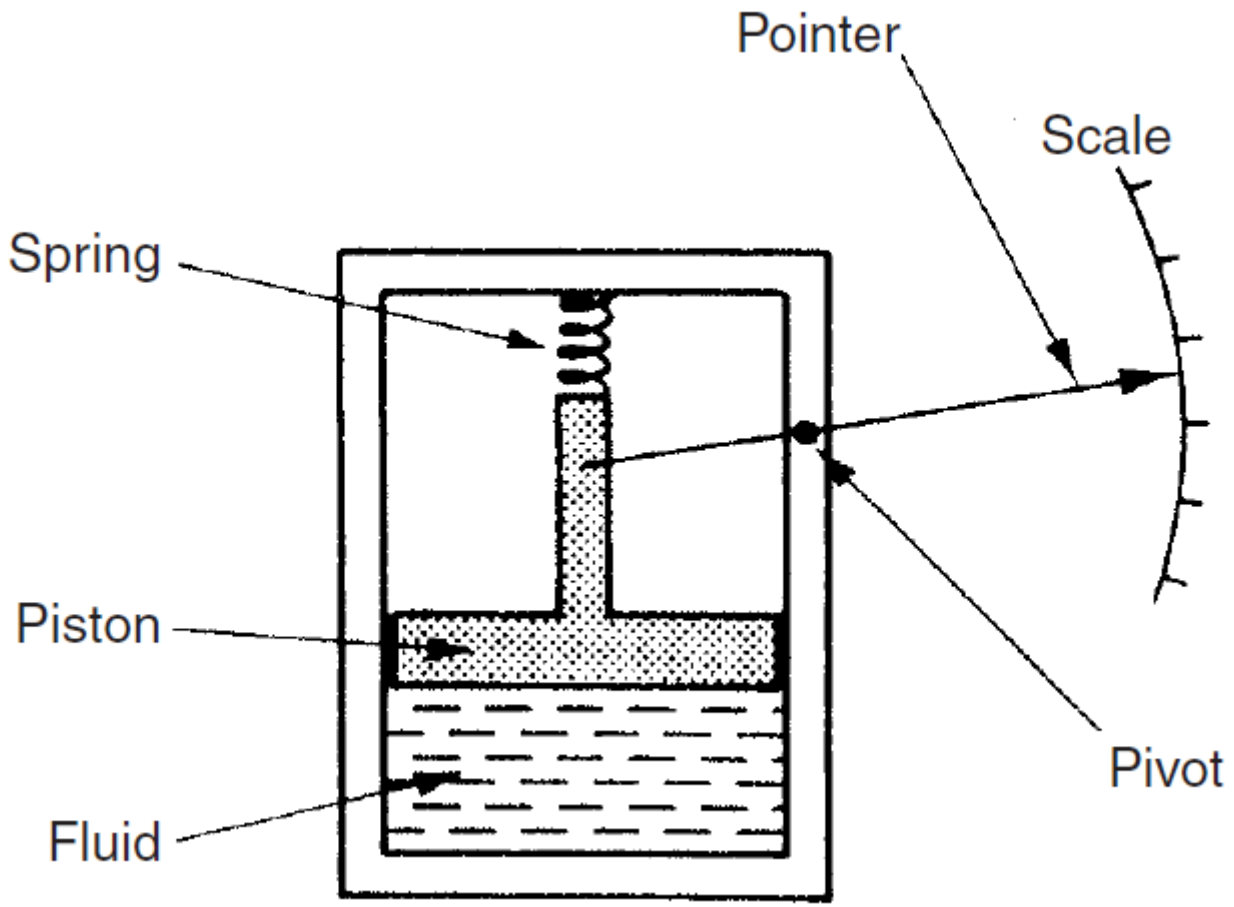
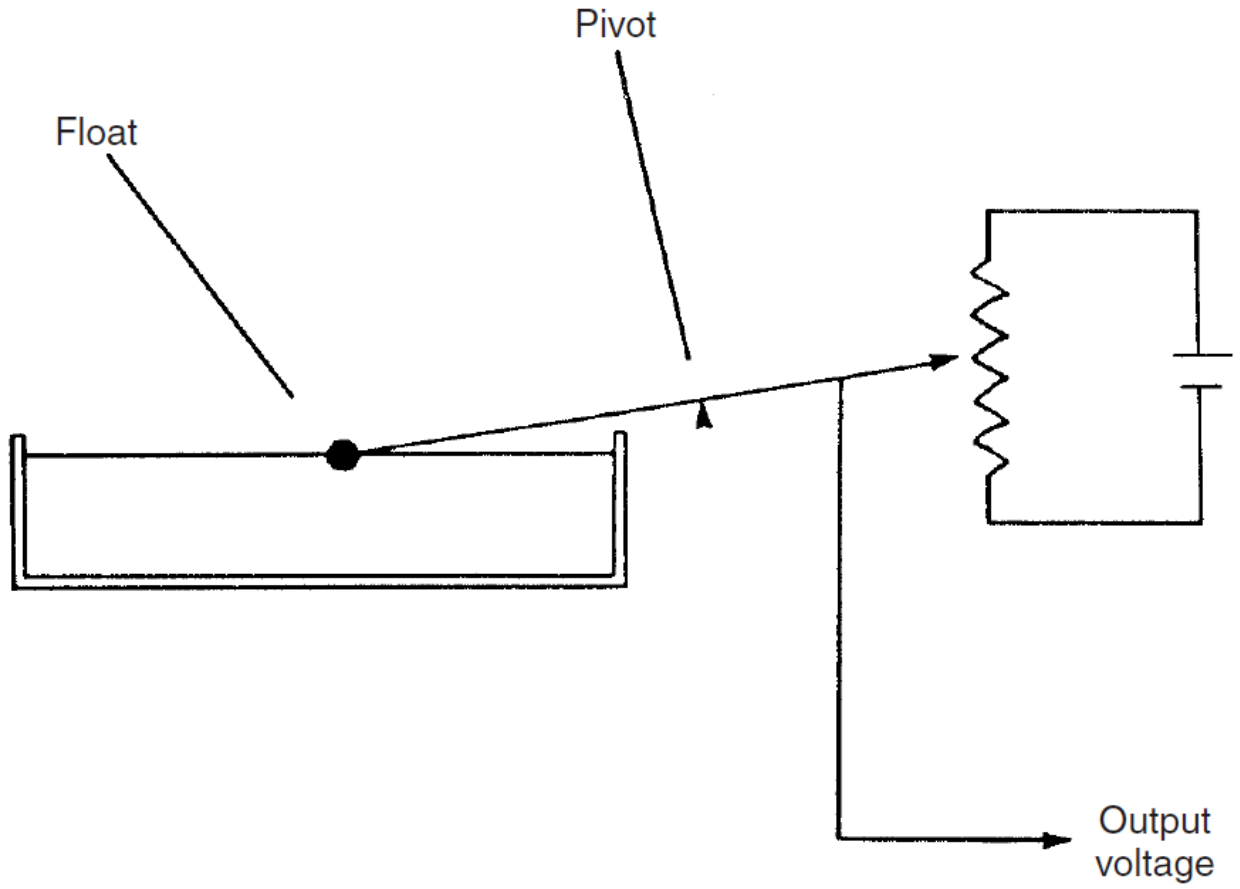
SENSOR CLASSIFICATIONS

- Passive and Active:
  - A passive sensor does not need any additional energy source and directly generates an electric signal in response to an external stimulus. That is, the input stimulus energy is converted by the sensor into the output signal. The examples are a thermocouple, a photodiode, and a piezoelectric sensor.
  - The active sensors require external power for their operation, which is called an excitation signal. That signal is modified by the sensor to produce the output signal.
  - The active sensors sometimes are called parametric because their own properties change in response to an external effect and these properties can be subsequently converted into electric signals. It can be stated that a sensor's parameter modulates the excitation signal and that modulation carries information of the measured value. For example, a thermistor is a temperature sensitive resistor.

ACTIVE AND PASSIVE INSTRUMENTS



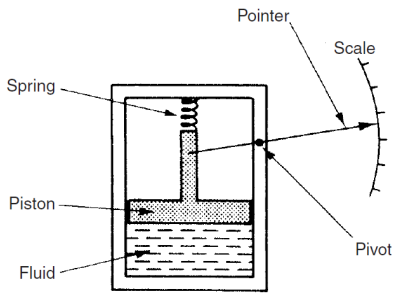
ACTIVE AND PASSIVE INSTRUMENTS

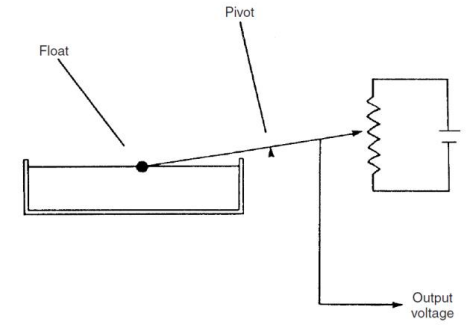


Petrol-tank level indicator.

ACTIVE AND PASSIVE INSTRUMENTS

- Level of **measurement resolution**
  - It is possible to increase measurement resolution by making the pointer longer
- In active instruments, adjustment of the magnitude of the external energy input allows much **greater control** over (caution: consideration of heating effects and for safety reasons)



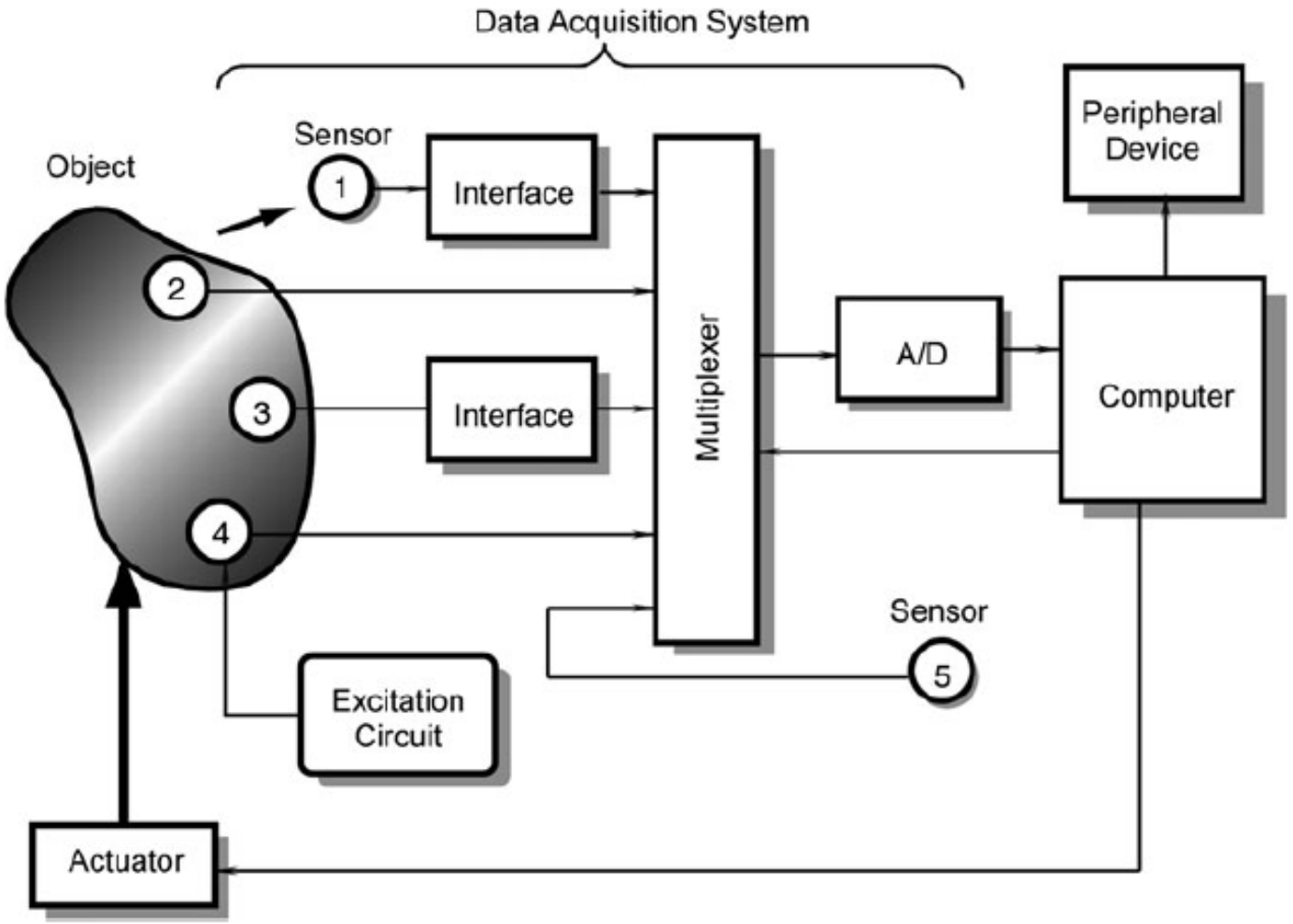


Petrol-tank level indicator.

ACTIVE AND PASSIVE INSTRUMENTS

- Level of measurement resolution
  - It is possible to increase measurement resolution by making the pointer longer
- In active instruments, adjustment of the magnitude of the external energy input allows much **greater control** over (caution: consideration of heating effects and for safety reasons)
- In terms of cost, passive instruments are normally of a more simple construction than active ones and are therefore **cheaper** to manufacture.
  - Choice between active and passive instruments for a particular application involves carefully balancing the measurement resolution requirements against cost

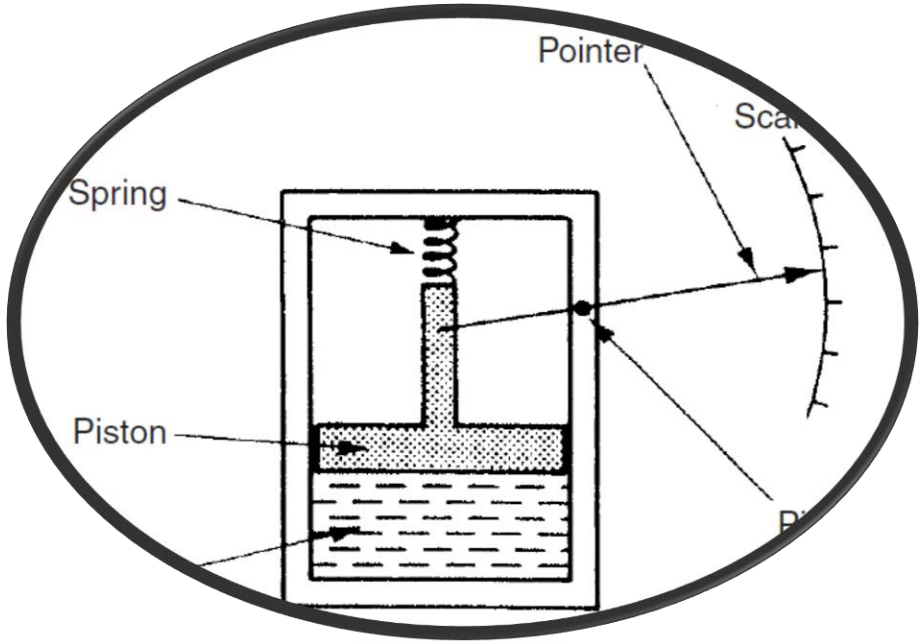
A SENSOR DOES NOT FUNCTION BY ITSELF

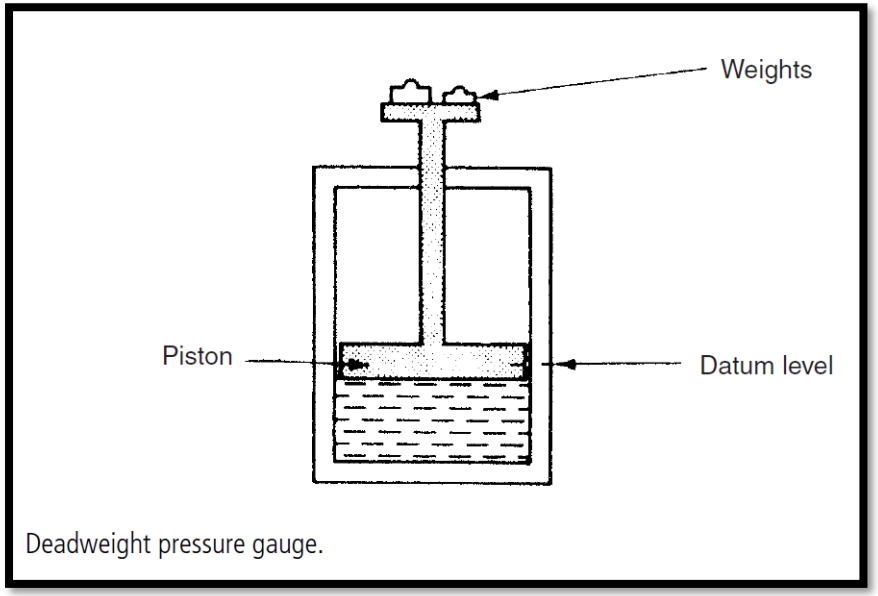


SENSOR CLASSIFICATIONS

- Sensors can be classified into **Absolute** and **Relative:**
  - An absolute sensor detects a stimulus in reference to an absolute physical scale that is independent of the measurement conditions, whereas a relative sensor produces a signal that relates to some special case.
  - An example of an absolute sensor is a thermistor, a temperature-sensitive resistor. Its electrical resistance directly relates to the absolute temperature scale of Kelvin.
  - Another very popular temperature sensor thermocouple is a relative sensor. It produces an electric voltage, which is a function of a temperature gradient across the thermocouple wires. Thus, a thermocouple output signal cannot be related to any particular temperature without referencing to a known baseline.
  - Another example of the absolute and relative sensors is a pressure sensor. An absolute pressure sensor produces signal in reference to vacuum – an absolute zero on a pressure scale. A relative pressure sensor produces signal with respect to a selected baseline that is not zero pressure, for example, to the atmospheric pressure.

NULL-TYPE AND DEFLECTION-TYPE INSTRUMENTS

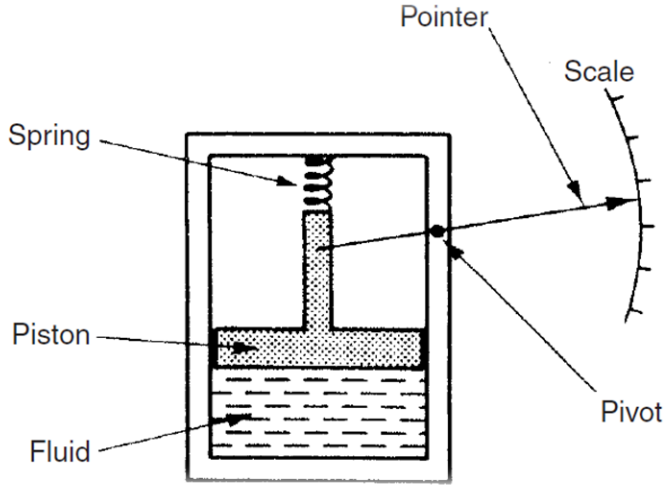


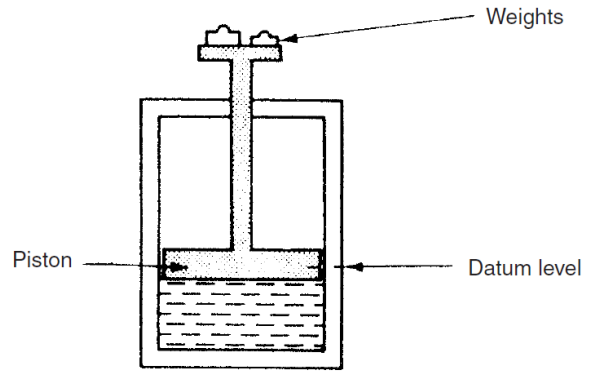


Deadweight pressure gauge.

NULL-TYPE AND DEFLECTION-TYPE INSTRUMENTS

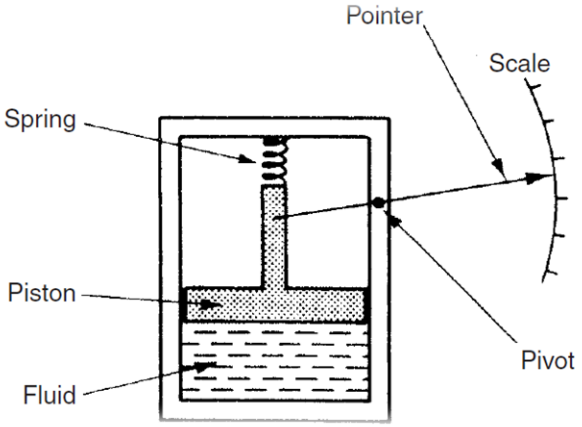
- Accuracy of Deflection Type Instrument depends on the linearity and calibration of the spring, whilst for the second it relies on the calibration of the weights.
- Calibration of weights is much easier than careful choice and calibration of a linear-characteristic spring, this means that the NULL type instrument will normally be the more accurate.



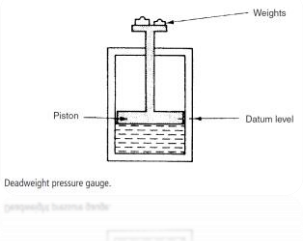


Deadweight pressure gauge.

NULL-TYPE AND DEFLECTION-TYPE INSTRUMENTS

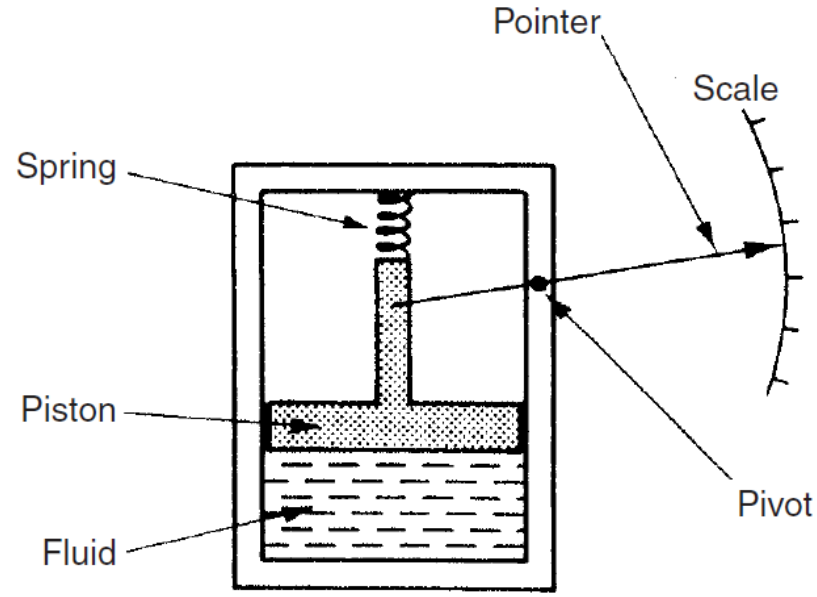


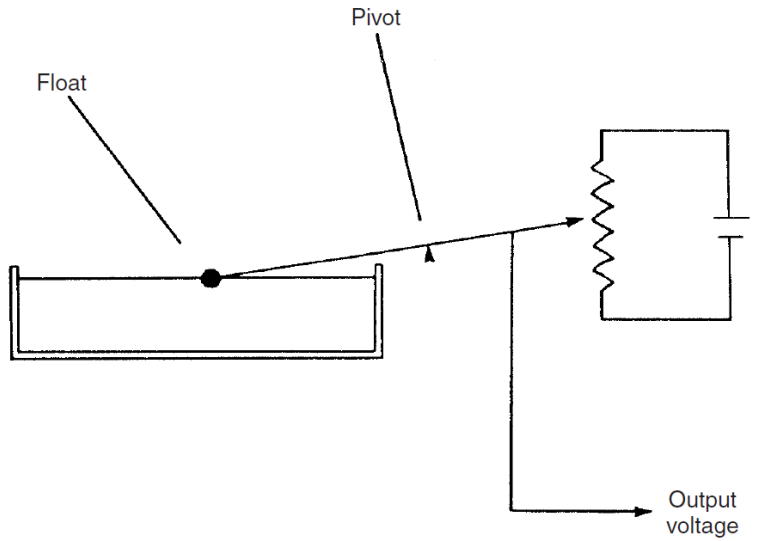
- Deflection type instrument is clearly more convenient.
  - It is far simpler to read the position of a pointer against a scale than to add and subtract weights until a null point is reached.
- A deflection-type instrument is therefore the one that would normally be used in the workplace. However, for calibration duties, the null-type instrument is preferable because of its superior accuracy.
  - The extra effort required to use such an instrument is perfectly acceptable in this case because of the infrequent nature of calibration operations



ANALOGUE AND DIGITAL INSTRUMENTS

- Analogue Instrument Defined:
  - An analogue instrument gives an output that varies continuously as the quantity being measured changes

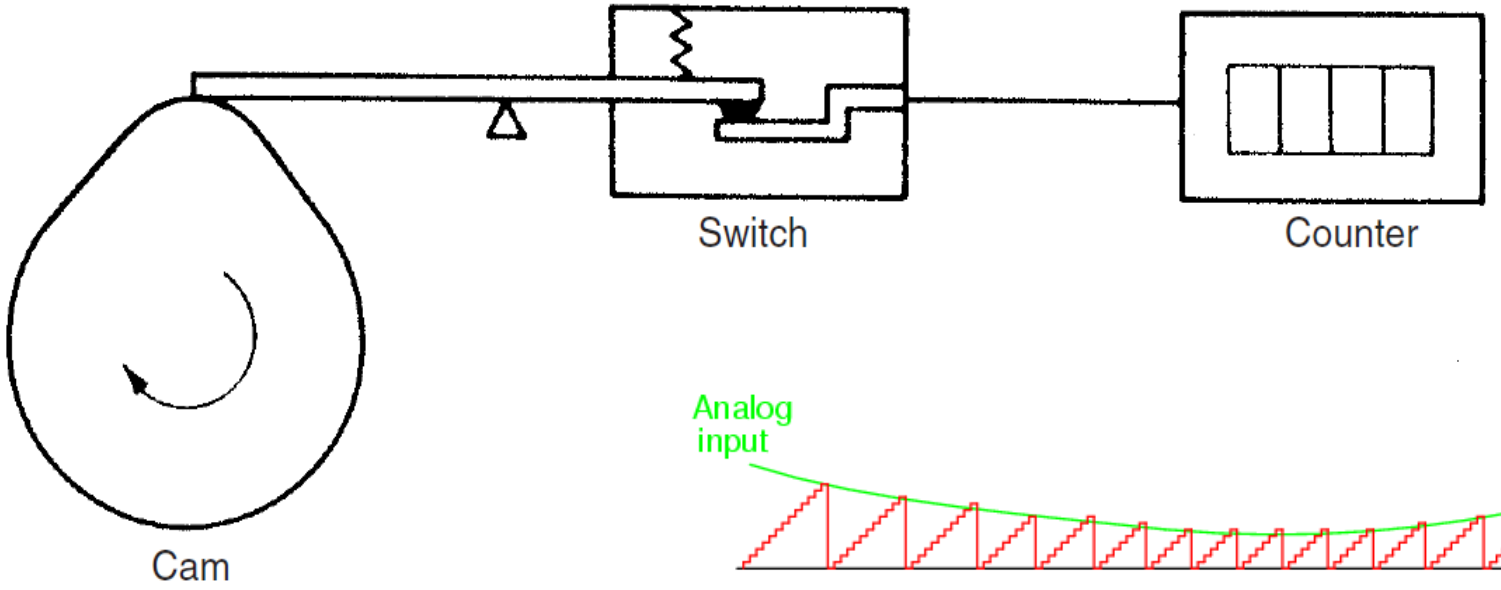


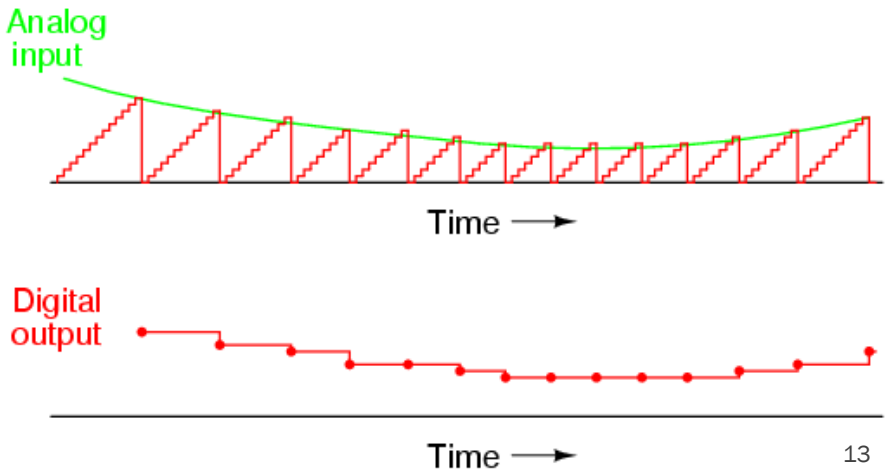


Petrol-tank level indicator.

ANALOGUE AND DIGITAL INSTRUMENTS

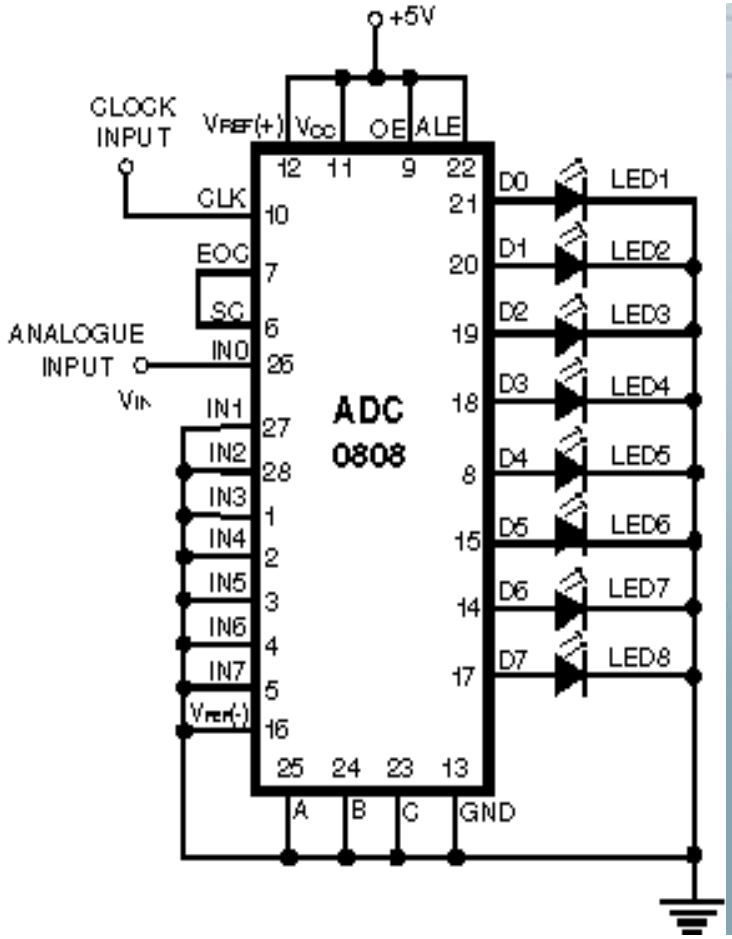
- Digital
- Discrete versus Digital

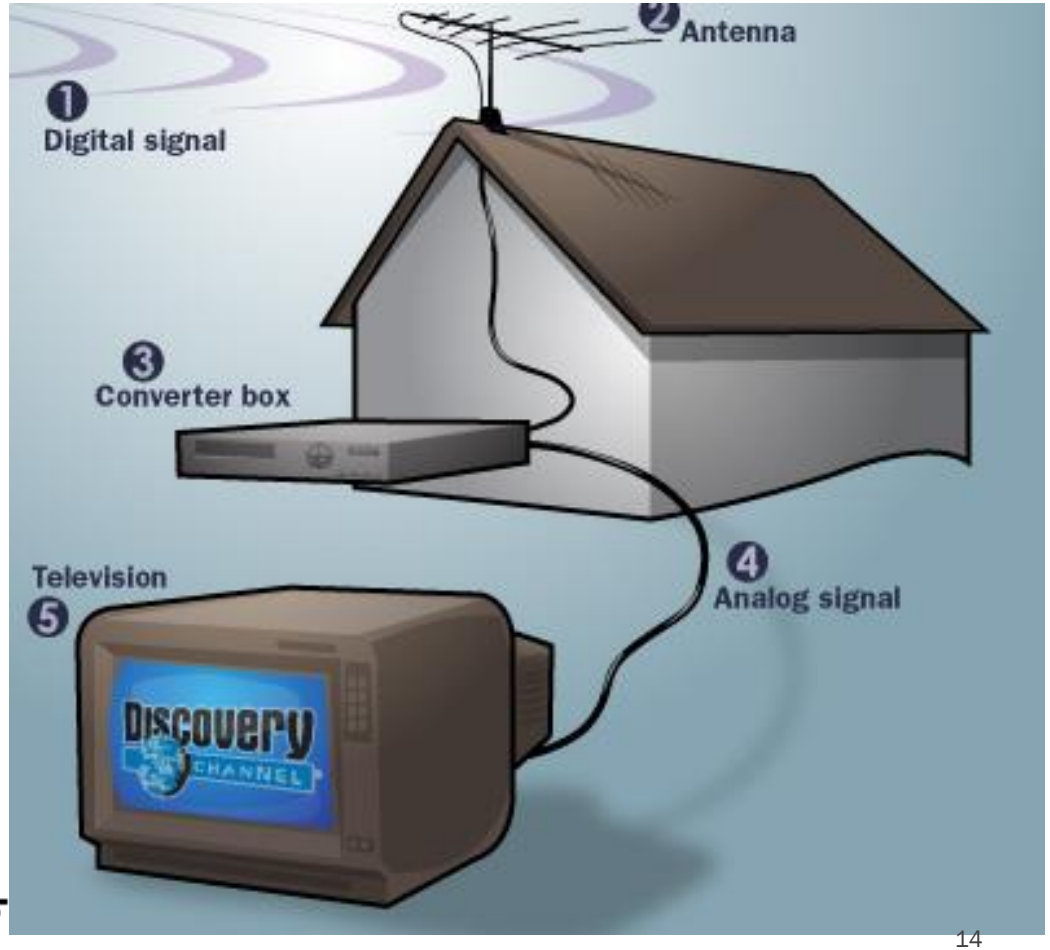




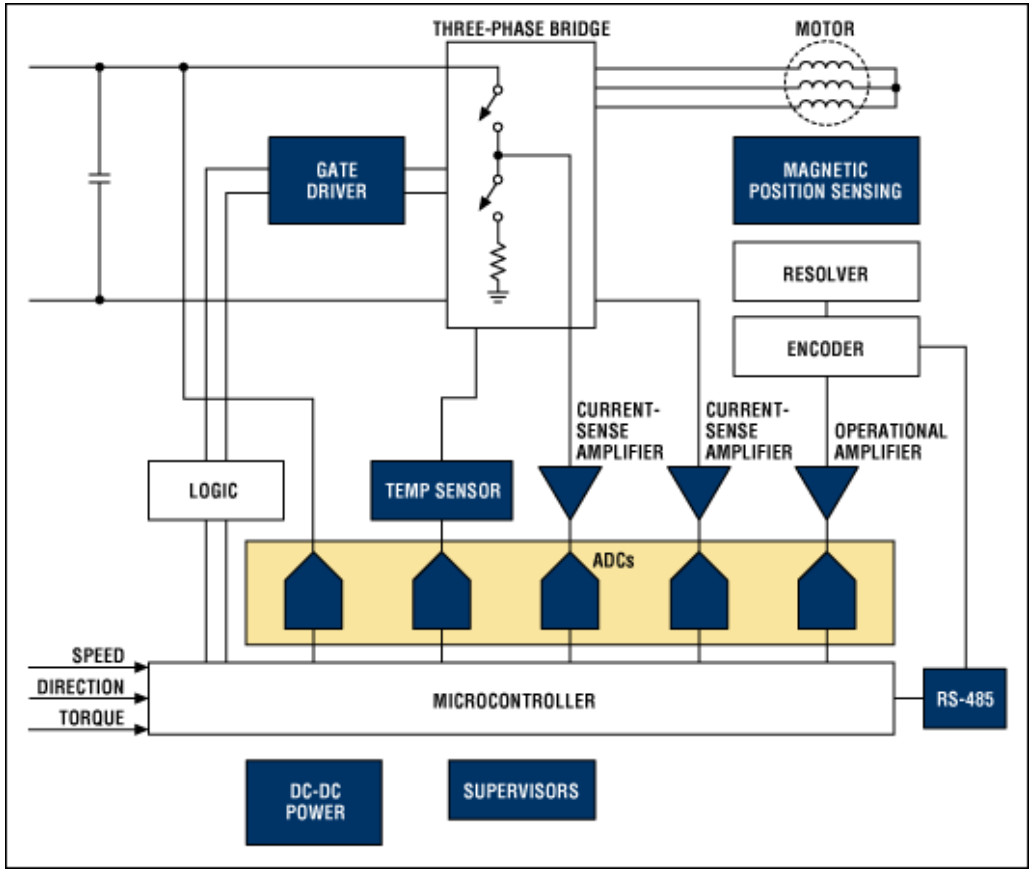
ANALOGUE AND DIGITAL INSTRUMENTS

- ADC or DAC Conversion





ANALOGUE AND DIGITAL INSTRUMENTS



PROBLEMS WITH ADC CONVERSION

- A/D converter adds a significant cost to the system.
- Finite time is involved in the process of converting an analogue signal to a digital quantity, and this time can be critical in the control of fast processes where the accuracy of control depends on the speed of the controlling computer.
  - Degrading the speed of operation of the control computer by imposing a requirement for A/D conversion thus impairs the accuracy by which the process is controlled.

CLASS ACTIVITY-1

THINK OF A SMALL SYSTEM THAT HAS SOME SENSING AND ACTUATING DEVICES AND ADD VALUE TO THE SURROUNDINGS

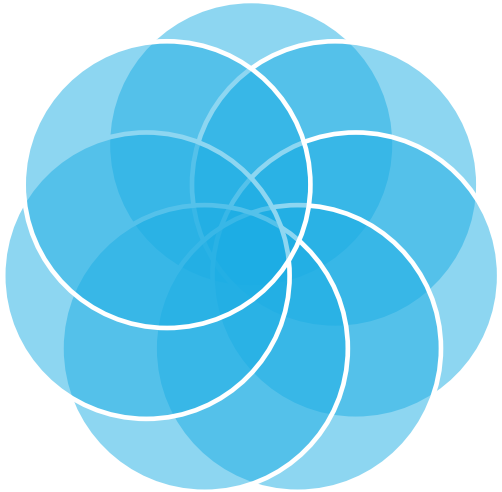
SENSOR SPECIFICATIONS

OVERLOAD CHARACTERISTICS

SENSITIVITY

RESOLUTION

OPERATING LIFE

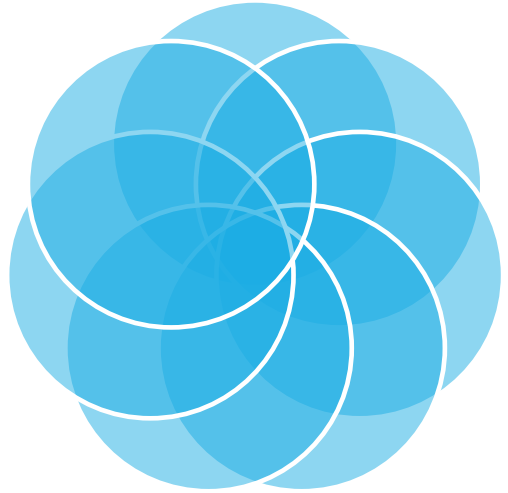


SPEED OF RESPONSE

STIMULUS

DEAD BAND

COST-SIZE-WEIGHT



ACCURACY

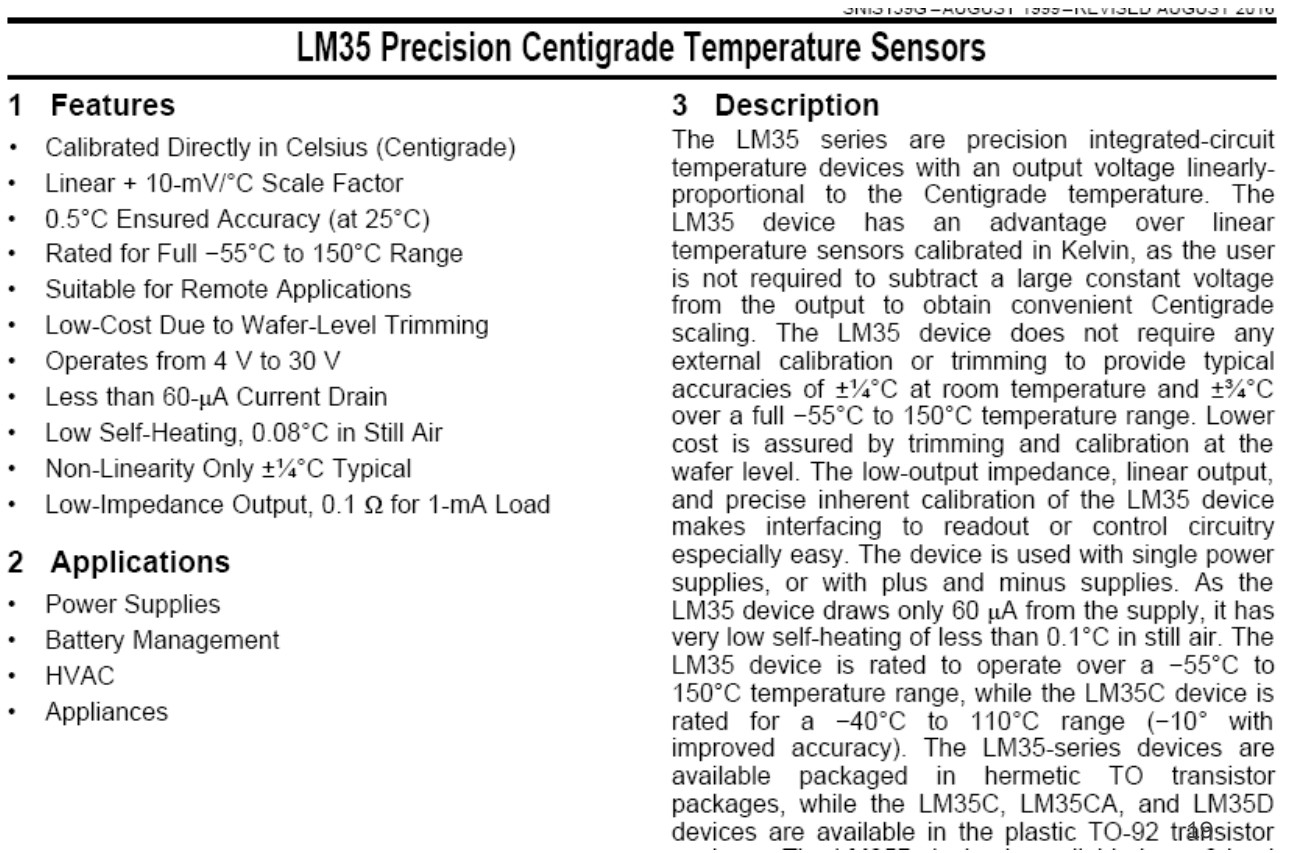
STABILITY

LINEARITY

ENVIRONMENTAL CONDITIONS

ACCURACY (OR INACCURACY)

- *accuracy* of an instrument is a measure of how close the output reading of the instrument is to the correct value.



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LM35 Precision Centigrade Temperature Sensors

1 Features

- Calibrated Directly in Celsius (Centigrade)
- Linear + 10-mV/°C Scale Factor
- 0.5°C Ensured Accuracy (at 25°C)
- Rated for Full −55°C to 150°C Range
- Suitable for Remote Applications
- Low-Cost Due to Wafer-Level Trimming
- Operates from 4 V to 30 V
- Less than 60-μA Current Drain
- Low Self-Heating, 0.08°C in Still Air
- Non-Linearity Only ±¼°C Typical
- Low-Impedance Output, 0.1 Ω for 1-mA Load

2 Applications

- Power Supplies
- Battery Management
- HVAC
- Appliances

3 Description

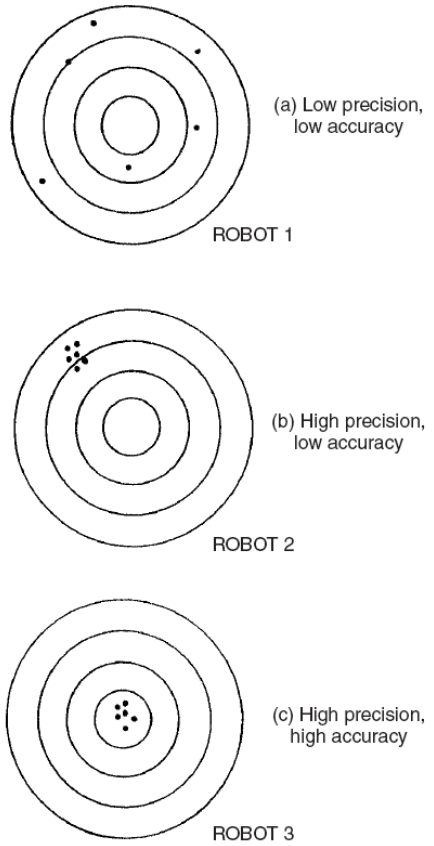
The LM35 series are precision integrated-circuit temperature devices with an output voltage linearly-proportional to the Centigrade temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. The LM35 device does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55°C to 150°C temperature range. Lower cost is assured by trimming and calibration at the wafer level. The low-output impedance, linear output, and precise inherent calibration of the LM35 device makes interfacing to readout or control circuitry especially easy. The device is used with single power supplies, or with plus and minus supplies. As the LM35 device draws only 60 μA from the supply, it has very low self-heating of less than 0.1°C in still air. The LM35 device is rated to operate over a −55°C to 150°C temperature range, while the LM35C device is rated for a −40°C to 110°C range (−10° with improved accuracy). The LM35-series devices are available packaged in hermetic TO transistor packages, while the LM35C, LM35CA, and LM35D devices are available in the plastic TO-92 transistor

ACCURACY (OR INACCURACY) VIZ-A-VIZ RANGE OF INSTRUMENT

- If, for example, a pressure gauge of range 0–10 bar has a quoted inaccuracy of ±1.0% f.s. (±1% of full-scale reading), then the maximum error to be expected in any reading is 0.1 bar.
- This means that when the instrument is reading 1.0 bar, the possible error is 10% of this value. For this reason, it is an important system design rule that instruments are chosen such that their range is appropriate to the spread of values being measured, in order that the best possible accuracy is maintained in instrument readings.
- **Thus, if we were measuring pressures with expected values between 0 and 1 bar, we would not use an instrument with a range of 0–10 bar.**

PRECISION/REPEATABILITY/REPRODUCIBILITY

- *Precision* is instrument's degree of freedom from random errors.
- If a large number of readings are taken of the same quantity by a high precision instrument, then the spread of readings will be very small.



Comparison of accuracy and precision.

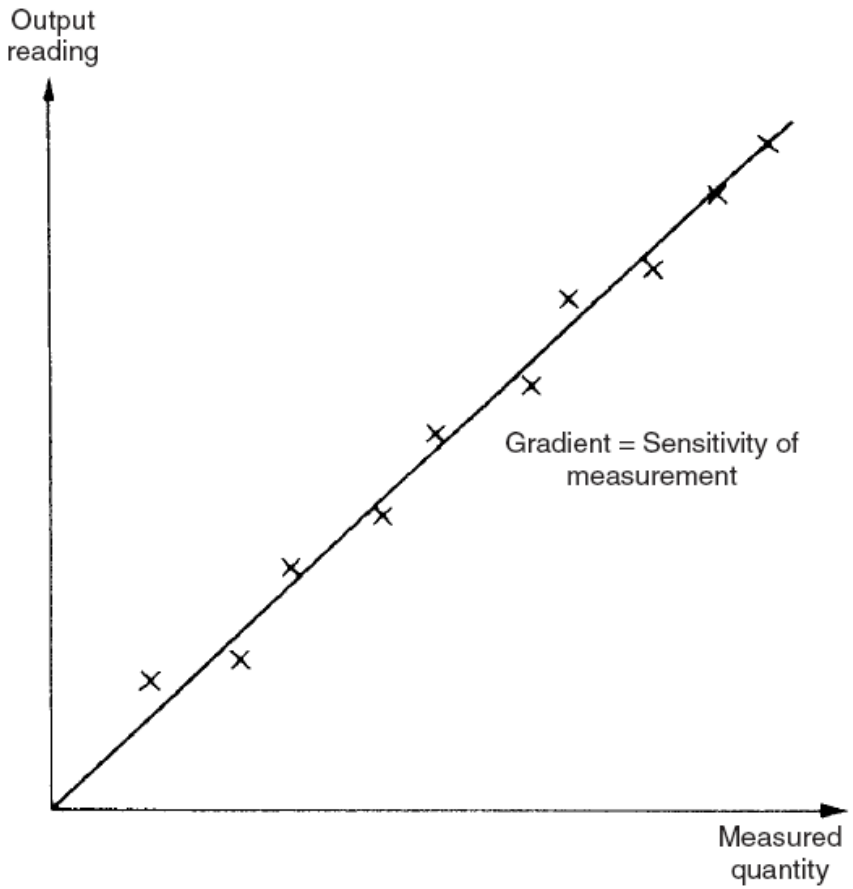
TOLERANCE

- **Tolerance** is a term that is closely related to accuracy and defines the maximum error that is to be expected in some value.
- Tolerance describes the maximum deviation of a manufactured component from some specified value.

RANGE OR SPAN

- The *range* or *span* of an instrument defines the minimum and maximum values of a quantity that the instrument is designed to measure.

LINEARITY & SENSITIVITY OF MEASUREMENT



$$\frac{\text{scale deflection}}{\text{value of measurand producing deflection}}$$

SENSOR PERFORMANCE CHARACTERISTICS

- The **transfer function** shows the functional relationship between physical input signal (s) and electrical output signal (S).

$$S = f(s)$$

- Ex:

$$V(Acc) = 1.5V + \left(Acc \times 167 \frac{mV}{g} \right)$$

TRANSFER FUNCTION AS GRAPH/CURVE

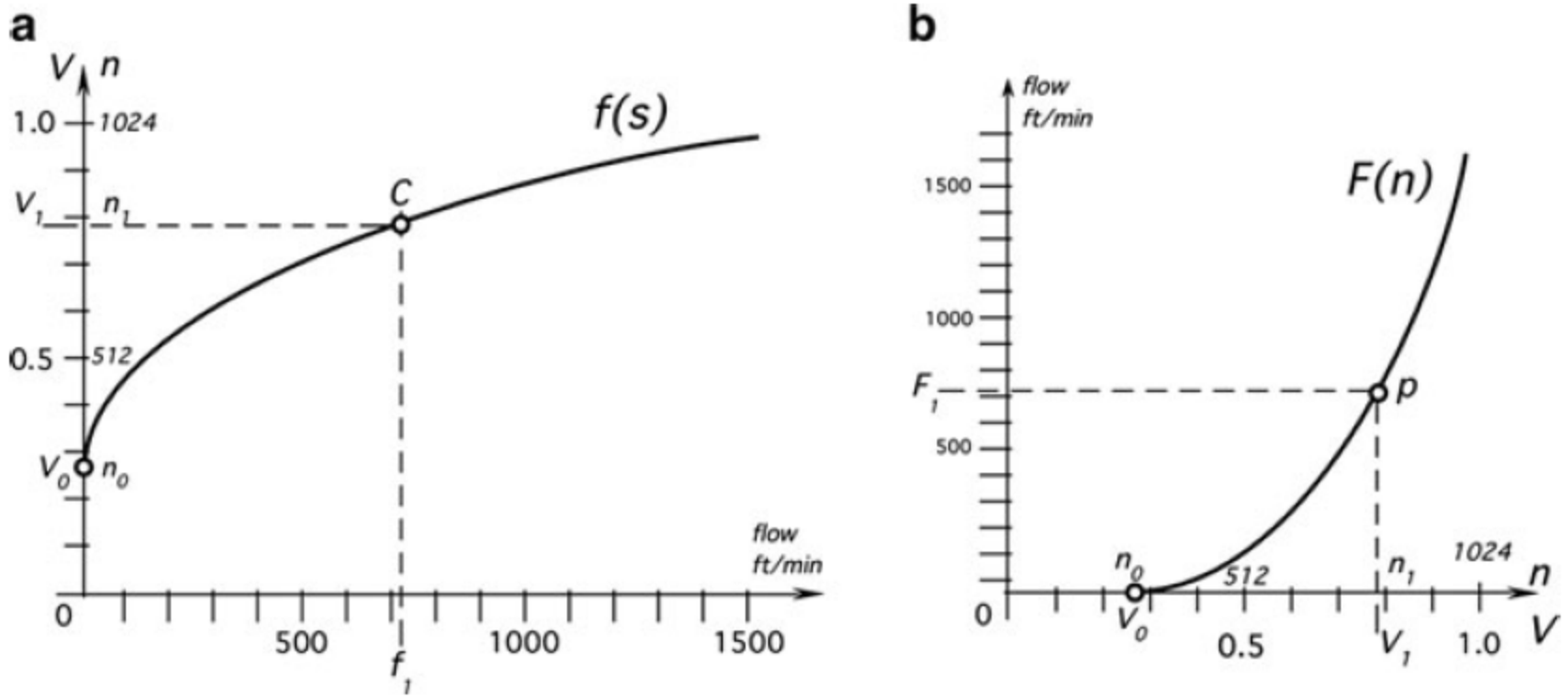


Fig. 2.1 Transfer function (**a**) and inverse transfer function (**b**) of a thermo-anemometer

SENSITIVITY

- Relationship between input physical signal and output electrical signal. It is the ratio between a small change in electrical signal to a small change in physical signal.
- Derivative of the transfer function with respect to physical signal. Typical units are volts/kelvin, millivolts/kilopascal, etc.
- A thermometer would have “high sensitivity” if a small temperature change resulted in a large voltage change.

CLASS QUIZ

The following resistance values of a platinum resistance thermometer were measured at a range of temperatures. Determine the measurement sensitivity of the instrument in ohms/°C.

Resistance (Ω)	*Temperature* (°C)
307	200
314	230
321	260
328	290

$$\text{measurement sensitivity} = 7/30 = 0.233\ \Omega/^{\circ}\text{C}.$$

SELF-TEST PROBLEM-1

A tungsten/5% rhenium–tungsten/26% rhenium thermocouple has an output e.m.f. as shown in the following table when its hot (measuring) junction is at the temperatures shown. Determine the sensitivity of measurement for the thermocouple in mV/°C.

mV	4.37	8.74	13.11	17.48
°C	250	500	750	1000

SELF-TEST PROBLEM-2

(a) An instrument is calibrated in an environment at a temperature of 20°C and the following output readings y are obtained for various input values x:

y	13.1	26.2	39.3	52.4	65.5	78.6
x	5	10	15	20	25	30

Determine the measurement sensitivity, expressed as the ratio y/x.

(b) When the instrument is subsequently used in an environment at a temperature of 50°C, the input/output characteristic changes to the following:

y	14.7	29.4	44.1	58.8	73.5	88.2
x	5	10	15	20	25	30

Determine the new measurement sensitivity. Hence determine the sensitivity drift due to the change in ambient temperature of 30°C.